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An experimental study of baseballs and softballs

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Abstract

The primary aim of this study is to experimentally evaluate the effects of seam orientation and angle of attack on aerodynamic drag for a series of commercially manufactured baseballs and softballs used in major tournaments. The aerodynamic forces and moments were measured experimentally over a range of wind speeds and angles of attack at different seam orientations with respect to the wind direction. The results indicate that the seam orientation had profound impact on aerodynamic characteristics of both baseball and softball. The average C_D variation between sides of baseball facing the wind can vary up to 16%. The results also indicate an increase of C_D values with the increase of angle of attack for all balls and seam positions tested.

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1. Introduction

The flight trajectories of sports balls largely depend on the aerodynamic characteristics caused by the physical shape of the balls. Depending on aerodynamic behaviour, the ball can be deviated significantly from its anticipated flight path resulting in a curved and unpredictable flight trajectory. Lateral deflection in flight, commonly known as swing, swerve, knuckle or curve, is well recognised in spherical ball games such as cricket, football, golf, tennis and volleyball. In most of these sports, the lateral deflection is produced by spinning the ball about an axis perpendicular to the line of flight or by other means to make asymmetric airflow around the ball. Hence, the aerodynamic properties of a sport ball is considered to be the fundamental aspect for players, coaches, regulatory bodies, ball manufacturers and even the spectators. It is widely recognised that baseball and softball games are national sports in the United States

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of America. It is at all levels (professional, amateur, and youth) now popular in North America, Japan, South Korea, Australia, New Zealand and many parts of Asia. Unlike a smooth sphere, baseball and softball are not uniformly smooth but are characterised by the yin – yang pattern of raised approximately 108 stitches for baseballs and 88 to 96 stitches for softballs. The stitches, seams, and their orientations can make the airflow around these balls complex and unpredictable. Although the aerodynamic behaviour of other sports balls have been studied by Mehta [1], Alam et al. [5] and Smith & Ogg [6], there are insufficient reliable experimental data of baseball aerodynamics available to the public domain except limited studies by Adair [2], Kensrud & Smith [3], Nathan [7] and Alam et al. [4]. In addition, none of these studies dealt with the aerodynamic behaviour under angles of attack. Thus, the primary objective of this work is to experimentally study the effects of seams under a range of angles of attack on aerodynamic drag of a series of commercially manufactured baseballs and softballs.

Nomenclature

A	projected frontal area (m^2)
C_D	drag coefficient (dimensionless)
D	aerodynamic drag force (N)
d	diameter of the ball (m)
Re	Reynolds number (dimensionless)
V	wind speed (m/s)
α	angle of attack (degree)
ρ	air density (kg/m^3)

2. Methods

2.1. Description of Balls

Three brand new commercial baseballs and two softballs were selected for this study. The baseballs were manufactured by Rawlings and Easton. These three balls are: (a) Rawlings NCAA Championship; (b) Rawlings Major League; and (c) Easton Model 600. These three balls have the same approximate diameter of 73 mm however their seam characteristics are significantly different. The NCAA and Easton balls have high and wider seams whereas the Major League ball has relatively flat and narrower seam widths. The NCAA ball also has larger gap between pair stitches compared to Major League and Easton. Nevertheless, all three balls have the same number of pair stitches (108). The frontal view and their seam orientations of these three baseballs are shown in Fig 1. Two selected softballs are: (a) Dudley Thunder SY; and (b) DeMarini Compression Controlled Polycore. The diameters of these two balls are approximately 90 mm and 98 mm respectively. The DeMarini softball has slightly larger diameter than the Thunder SY softball. However, these two balls possess the same 88 pair of stitches. The DeMarini ball has slightly higher and wider seams than the Thunder SY ball. The frontal views and their seam orientations of two softballs are shown in Fig 2.

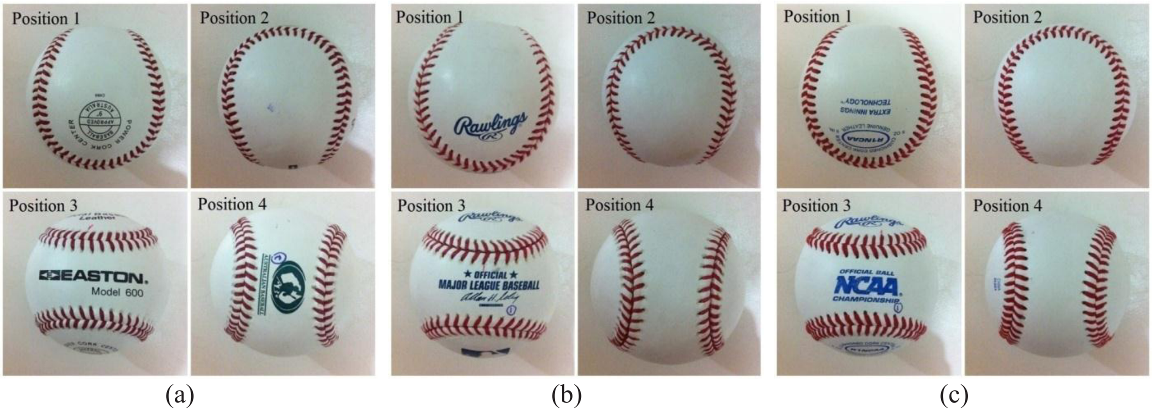


Fig. 1. Frontal view of seam positions for baseballs: (a) Easton Model 600; (b) Rawlings Major League; (c) Rawlings NCAA

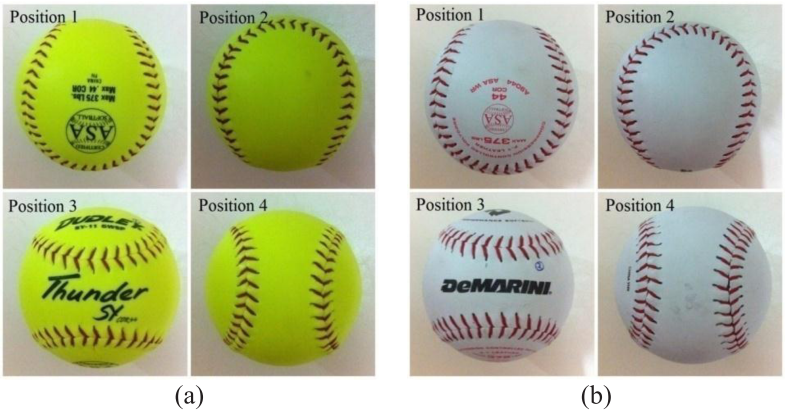


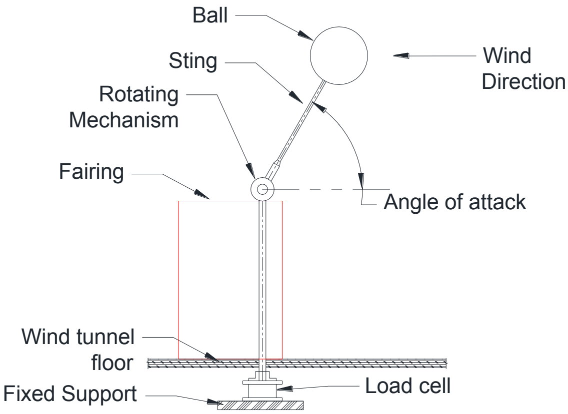
Fig. 2. Frontal view of seam positions for softballs: (a) Dudley Thunder SY; and (c) DeMarini Compression Controlled Polycore

2.2. Experimental procedure

In order to investigate the aerodynamic properties experimentally, a support system made of a sting with an angle adjustment mechanism (as shown in Fig 3) was developed to hold the baseball and softball on a force sensor in the wind tunnel. The distance between the bottom edge of the ball and the tunnel floor was 400 mm, which was well above the tunnel boundary layer and out of the ground effect completely. An aerofoil (fairing) with the same height as the sting was positioned around it (see Fig 3). The aerofoil shaped fairing would protect the sting from the incoming wind load and greatly enhance the accuracy of the results since the previous experimental setup [4] overestimated the magnitude of the drag force when compared to published data.

The ball was connected through a mounting sting with a JR3 multi-axis load cell (also commonly known as a 6-degree of freedom force-torque sensor made by JR3, Inc., Woodland, USA). A purpose made computer software was used to digitize and record all three forces (drag, side, and lift forces) and three moments (yaw, pitch and roll moments) simultaneously. Each set of data was recorded for 20 seconds time average with a frequency of 20 Hz ensuring electrical interference is minimal. Multiple data sets were collected at each speed tested and the results were averaged for minimising the further possible errors in the raw experimental data.

All 5 balls were tested at four seam orientations (see Fig 1 and Fig 2) facing the wind with respect to four different angles of attack (α = 90°, 75°, 60° and 45°) using the RMIT Wind Tunnel. The maximum speed of the tunnel is approximately 145 km/h. The rectangular test section's dimension is 3 m (wide) × 2 m (height) × 9 m (long). More details about the tunnel can be found in Alam et al. [8]. The baseballs and softballs were tested over a range of wind speeds from 30 to 130 km/h with an increment of 10 km/h.



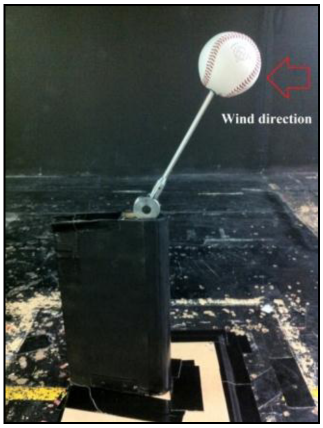


Fig. 3. Experimental setup: (a) schematic; (b) inside wind tunnel test section

The aerodynamic drag force (D) on the balls at different wind speeds was initially measured and converted to a dimensionless parameter: drag coefficient (C_D). The C_D is defined as:

$$C_D = \frac{D}{\frac{1}{2}\rho V^2 A} \tag{1}$$

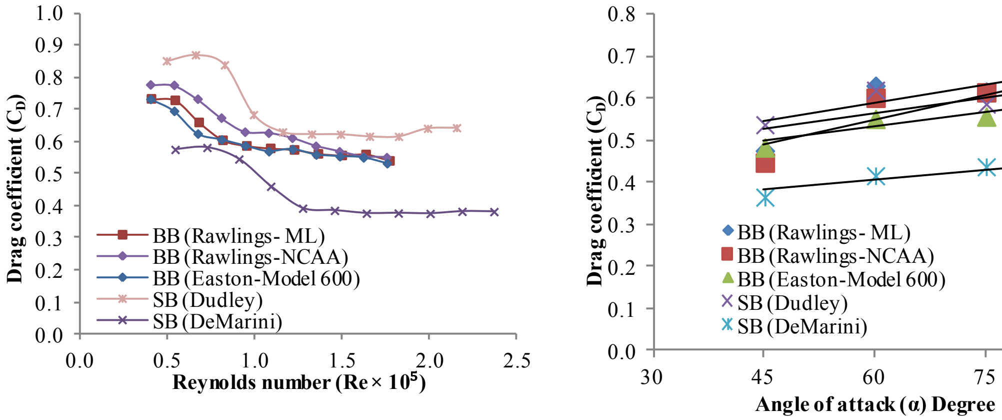
The Reynolds number (Re) was calculated using the formula:

$$Re = \frac{\rho V d}{\mu} \tag{2}$$

The lift and side forces and their coefficients were not determined and presented in this paper. Only drag coefficients are presented here. The repeatability of the measured forces was within ±0.01 N and the wind velocity was less than ±0.5 km/h.

3. Results and discussion

For the baseline comparison of the experimental data, drag coefficient (C_D) values at seam position-1 and angle of attack, α = 90° for all 5 balls are plotted at different Reynolds numbers (Re) tested as shown in Fig 4(a). Fig 4(b) shows the variation of average C_D values with angles of attack. Average C_D variations with Re for four seam positions with respect to wind direction are shown in Fig 5.



(a) (b)

Fig. 4. Experimental data at baseline position (seam position-1 & angle of attack, $\alpha = 90°$): (a) C_D variations with Reynolds numbers; (b) Average C_D variation with angles of attack

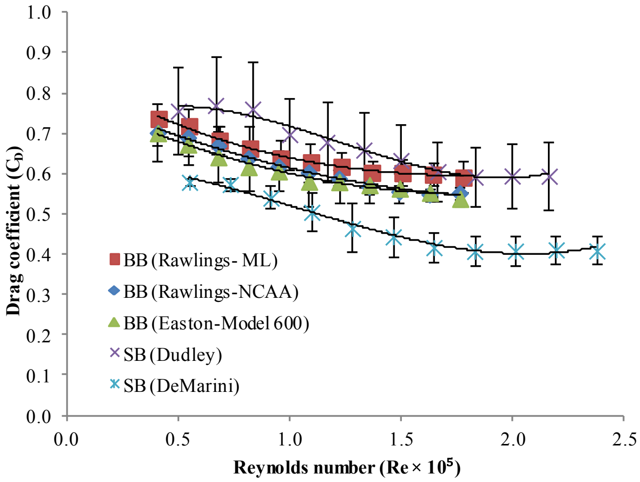


Fig. 5. Average drag coefficient (C_D) variation with Reynolds number (*Re*) for four seam positions with respect to wind direction

As in rough spheres, there is an expected drag crisis, while compared to published data [4], there is significant drag crisis due to the flow transition from laminar to turbulent flow regime for all 3 baseballs. Rawlings NCAA data showed drag crisis region with a minimum average C_D as low as 0.52 (see Fig 4a). This value is 21.2% higher than the published data for rotating baseball [3]. The flow transition from laminar to turbulent seems to start at around 40 km/h ($Re = 0.52 \times 10^5$) for all 3 baseballs and becomes fully turbulent at around 120 km/h wind speeds (e.g., $Re = 1.5 \times 10^5$). The average C_D values after the transition for the three baseballs are 0.52. It may be noted that the transition to fully turbulent flow for Rawlings Major League ball (with lower seam height) occurs at slightly higher speeds compared to Rawlings NCAA Champion ball with higher seam height. The minimal difference in C_D values for higher and lower seam height baseballs after transition indicates that the local flow separation due to seams is minimised or fully eliminated. The effect of seam and stitches are highly evident at low speeds as the local flow separation is present due to seams, stitches and their complex orientations. The DeMarini softball displays the lowest C_D value compared to Thunder SY softball as well as baseballs (see Fig 3). The flow transition for both softballs starts later at 65 km/h compared to 40 km/h for baseballs and becomes fully turbulent at 120 km/h.

The variations of C_D values among all four seam positions (1, 2, 3 and 4) as shown in Fig 2 and Fig 3 are evident at all Reynolds numbers tested for all 3 baseballs and 2 softballs, however, the variations between position 1 and 2, and position 3 and 4 are minimal as these two positions are considered to be the mirror image. Additionally, the C_D variations among four positions for each ball are evident at low Reynolds number (below 40 km/h), however, these variations are minimal at high Reynolds numbers ($Re = 1.6 \times 10^5$ or above) which is believed to be due to the elimination or minimization of local flow separations from seams. The average C_D value for all four seam positions for the three baseballs is approximately 0.57 which is slightly lower compared to published data [2]. It is believed that most of the published data was obtained using a low turbulence smooth wind tunnel whereas the turbulence intensity of RMIT Industrial Wind Tunnel is around 1.8%. The flow transition effect for baseball is not clearly evident under the range of speeds tested in this study.

The angle of attack has notable impact on C_D value for both baseball and softball. For a smooth sphere, the angle of attack has no effect as the flow is symmetrical regardless the flow orientation. However, the baseball and softball are not fully symmetrical due to their complex seam orientation, seam geometry (height and width) and number of stitches. This asymmetry causes not only drag but also side and lift forces as a function of angle of attack. It was also noted in Fig 4b that the average C_D value for all three baseballs and two softballs increases approximately 23% with the increase of angle of attack between 45° and 90°.

4. Conclusions

- The average C_D value for a baseball and softball at high Reynolds number (120 km/h and above) is approximately 0.57 and 0.50, however, at low Reynolds number (40 km/h) the value could be as high as 0.70 and 0.67 respectively.
- Seam orientation and stitches have significant effects on baseball aerodynamics. The average variation of C_D value between sides of baseball facing the wind can vary up to 16%.
- The C_D value increases (approximately 23%) with the increase of angle of attack for all balls and positions tested.

References

[1] Mehta RD. Aerodynamics of Sports Balls. *Annual Review of Fluid Mechanics* 1985;**17**:151-189.

[2] Adair RK. The physics of baseball. *Physics Today* 1995;**48**:26-31.

[3] Kensrud JR, Smith LV. In situ drag measurements of sports balls. *Procedia Engineering* 2010;2:2437-2442.

[4] Alam F, Ho H, Smith L, Subic A, Chowdhury H, Kumar A. A study of baseball and softball aerodynamics. *Procedia Engineering* 2012;**34**:86-91.

[5] Alam F, Chowdhury H, Stemmer M, Wang Z and Yang J. Effects of surface structure on soccer ball aerodynamics. *Procedia Engineering* 2012;**34**:86-91.

[6] Smits AJ, Ogg S. Golf ball aerodynamics. *The Engineering of Sport 5* 2004;**1**:3-12.

[7] Nathan AM. The effect of spin on the flight of a baseball. *American Journal of Physics* 2008;**76**:119-124.

[8] Alam F, Watkins S, Zimmer G. Mean and time-varying flow measurements on the surface of a family of idealised road vehicles. *Experimental Thermal and Fluid Science* 2003;**27**:639-654.